High Resolution Time Series Measurements of Bio-optical and Physical Variability in the Coastal Ocean as Part of HyCODE

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LONG-TERM GOAL

The long-term goal of this project is to increase understanding of the variability of inherent and apparent optical properties (IOPs and AOPs) of ocean waters and their relationships to each other as well as to physical processes on continental shelves. Data collected during our study and their analyses will expand the usefulness and utility of remotely sensed ocean color data, which are and will be collected from Navy hyperspectral imagers flown on both aircraft and spacecraft.

OBJECTIVES

Specific objectives of the project are

1. To provide the maximum number of *in situ* observations (highest possible number of match-ups) of IOPs and AOPs possible for calibrating, groundtruthing, and relating subsurface optical properties (algorithm development) to aircraft and spacecraft ocean color data, and to develop, test, and validate optical models and high resolution interdisciplinary models of the coastal ocean.

2. To study processes which contribute to temporal and spatial (horizontal and vertical) variability of spectral IOPs and AOPs. In particular, we are determining how temporal and spatial variability in IOPs and AOPs are affected by:

a) Coastal physical and biological dynamics (upwelling/downwelling, fronts, filaments, eddies, blooms, etc.) and larger scale circulation patterns

b) Wave fields (e.g., tides and surface, internal, and solitary waves)

c) Water column stratification and current shears

d) Near surface and near bottom mixing (e.g., effects on primary productivity, sediment resuspension, dilution, dispersion, etc.)

e) Diurnal and seasonal biological and physical cycles

f) Riverine and runoff inflows (i.e., changes in partitioning of sedimentary, biological, and colored dissolved material (CDM) components, buoyant plumes, and phytoplankton blooms).

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14. ABSTRACT

The long-term goal of this project is to increase understanding of the variability of inherent and apparent optical properties (IOPs and AOPs) of ocean waters and their relationships to each other as well as to physical processes on continental shelves. Data collected during our study and their analyses will expand the usefulness and utility of remotely sensed ocean color data, which are and will be collected from Navy hyperspectral imagers flown on both aircraft and spacecraft.

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\APPROACH

Intensive HyCODE field observations were made in the summers of 2000 and 2001. The particular region of study for this project is the continental shelf off New Jersey (Figure 1a) where coastal upwelling fronts, riverine plumes, and internal solitary waves are common features. Our work is part of a large coordinated effort involving several other institutions (Dickey et al., 1999). The UCSB/OPL HyCODE mooring (Figure 1b) was deployed by OPL engineers, Derek Manov and Frank Spada, on May 16, 2000 on the New Jersey shelf (~24 m depth). This mooring was serviced and redeployed on July 25 and recovered on September 15, 2000. High temporal resolution measurements of IOPs and physical properties were collected at multiple depths. Hyperspectral instruments to measure AOPs were deployed in addition to the physical and IOP-optical instruments during the summer 2001 field program. The data collected were processed and analyzed by OPL researchers Songnian Jiang and Grace Chang, respectively. Collaborative efforts were and will be made with other HyCODE investigators, e.g., Oscar Schofield and Scott Glenn (Rutgers University), Mark Moline (Cal Poly), Emmanuel Boss and W. Scott Pegau (OSU), and Alan Weidemann (NRL, Stennis). Additional details may be found in Dickey et al. (1999) or on the web site: http://www.opl.ucsb.edu/hycodeopl.html .

WORK COMPLETED

We completed deployment and recovery of the first, second, and third HyCODE mooring deployments spanning the periods of May 16 - July 25, 2000; July 25 - September 15, 2000; and June 20 – August 7, 2001, respectively. All data have been processed. Datasets were complete with little to no bio-fouling seen in optical signals (see data reports by Chang et al., 2000; Dickey et al., 2000). Summer 2000 data and data reports have been made available to other HyCODE investigators via a CD-ROM. Time series from the summer 2000 study are shown and described in Figures 1c and d and Figure 2.

A paper describing some of the results from the 2000 field observations has been submitted to the Journal of Geophysical Research (Chang et al., 2001). Mid-shelf mooring and tripod data and nearshore node data (courtesy of O. Schofield, M. Moline, and A. Weidemann) were analyzed statistically (frequency autospectra, coherence, autocorrelations, etc.) to investigate the temporal and spatial variability of hydrographic, physical, biological, and optical properties on scales of minutes to months and meters to ~50 km and to examine differences between nearshore and mid-shelf processes (Chang et al., 2001).

RESULTS

The major processes contributing to bio-optical variability in summer 2000 were identified: e.g., coastal jet, upwelling front, tides, river flows, and internal solitary waves (Chang et al., 2001). It was found that temporal decorrelation scales of optical and biological properties increased from nearshore (~1 day) toward the mid-shelf (2-3 days), whereas decorrelation scales for hydrographic properties were 2-3 days at both locations (Chang et al., 2001). Absorption at the mid-shelf location was dominated by phytoplankton and colored dissolved organic matter (CDOM), each accounting for roughly 50% of all absorbing materials at 440 nm. On the other hand, nearshore absorption was mainly influenced by particulate material (~70% of absorbing material) as compared to CDOM (~30% of absorbing material). Phytoplankton dominated the turbidity near the surface and intermediate depths and detritus dominated near the bottom. The interaction of tidal currents with the mean currents and the water mass/turbidity front were important for the formation of small-scale

convergence and divergence zones (on the order of a few km) in the HyCODE experimental region. Frequency autospectra revealed that the M2 semidiurnal tides dominated temporal variability of physical, hydrographic, optical, and biological properties in both the nearshore and mid-shelf regions (Chang et al., 2001).

Time series of remote sensing reflectance were generated utilizing the optical model Hydrolight 4.0 (Mobley, 1994) and UCSB OPL mooring IOP data. Preliminary analyses of Hydrolight-generated $R_{rs}(\lambda)$ time series show that low salinity water masses in spring 2000, likely from the Hudson River, greatly influenced the optical properties at the HyCODE site. Correlations between $a_{t\text{-}w}(412)$:$a_{t\text{-}w}(676)$, $a_{t\text{-}w}(676)$-$a_{t\text{-}w}(650)$ (a proxy for phytoplankton), and $b_{t\text{-}w}(412)$ versus the reciprocal of salinity (salinity^{-1}) show that these river flows resulted in increased CDOM in near-surface water. Spectral shifts of $R_{rs}(\lambda)$ were detected as well; the ratio of $R_{rs}(405)$:$R_{rs}(675)$ increased from ~1.25 during times of particulate-dominated waters to >2 during times of CDOM-dominated near-surface waters.

Closure analyses between Hydrolight-generated (Mobley, 1994), and TSRB- and profiled radiometer-measured and calculated (using the relationship: $k_u = (-1/\Delta z) * \ln(L_u(\lambda)_2/L_u(\lambda)_1)$ upwelling and water-leaving radiance ($L_u(\lambda)$ and $L_w(\lambda)$, respectively) were performed with summer 2000 HyCODE data (courtesy of E. Boss and W. S. Pegau). These closure analyses resulted in r^2 of >0.95 and percent errors of less than 25% on average between measurement methods for $L_w(\lambda)$. Results from these analyses will prove useful for groundtruthing of remotely sensed data.

IMPACT/APPLICATION

It is anticipated that results of the project will lead to 1) improved understanding of variability of inherent and apparent optical properties (IOPs and AOPs) and their relationships to each other as well as to physical processes on the ocean's continental shelves, 2) expanded usefulness and utility of high spectral and spatial resolution remotely sensed ocean color data, and 3) more accurate predictive interdisciplinary models of the coastal ocean. All three of these points are fundamental to tactical naval applications in the coastal ocean and central to the ONR HyCODE program.

TRANSITIONS

Results from our statistical time series analyses will facilitate the development of interdisciplinary models (e.g., to predict the movement and distribution of biology, and study the anthropogenic effects on the coastal ocean) and to aid in the development and testing of ocean color algorithms to derive organic matter and primary production from remotely sensed data. Results of our work (see impacts above) should also be of interest to several levels of the operational Navy, particularly naval operations in the littoral zone.

RELATED PROJECTS

This project builds on the ONR Coastal Mixing and Optics (CMO) and PRIMER programs (see. http://www.opl.ucsb.edu/cmo.html). Results of our CMO work have already appeared in the reviewed literature (JGR, volume 106, number C5) as well as reports and conference proceedings (please see CMO Annual Report in this volume). Our HyCODE activity involves close collaborations with several other HyCODE, Naval Research Laboratory (NRL), and LEO-15 scientists. Our activity was also

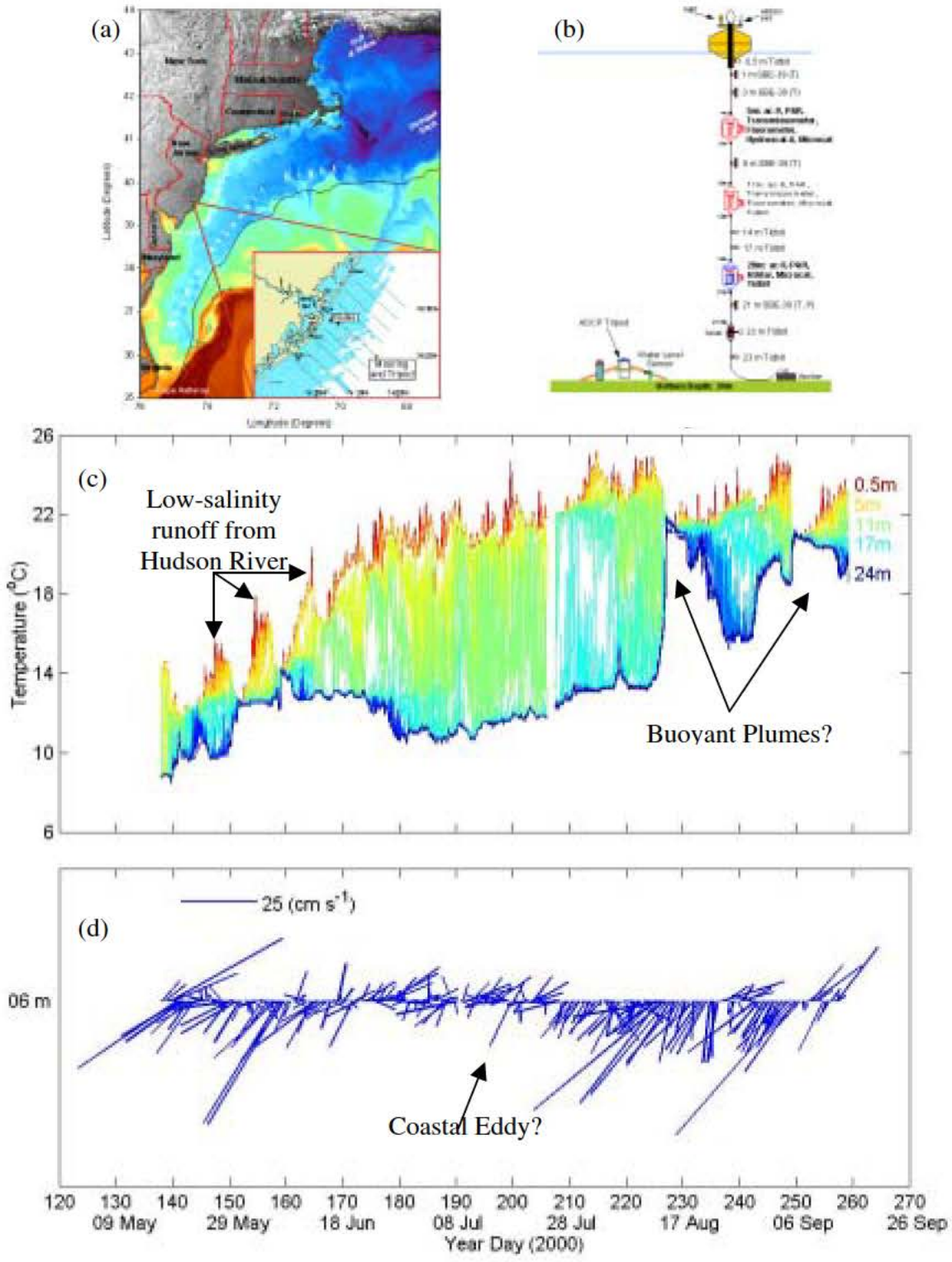

Figure 1. (a) Map of the Middle Atlantic Bight. Inset: site map of the HyCODE field experiment. (b) Schematic diagram of UCSB mooring and tripod. (c) Time series of temperature. (d) Stickplot of de-tided ADCP-measured currents at 6 m water depth.

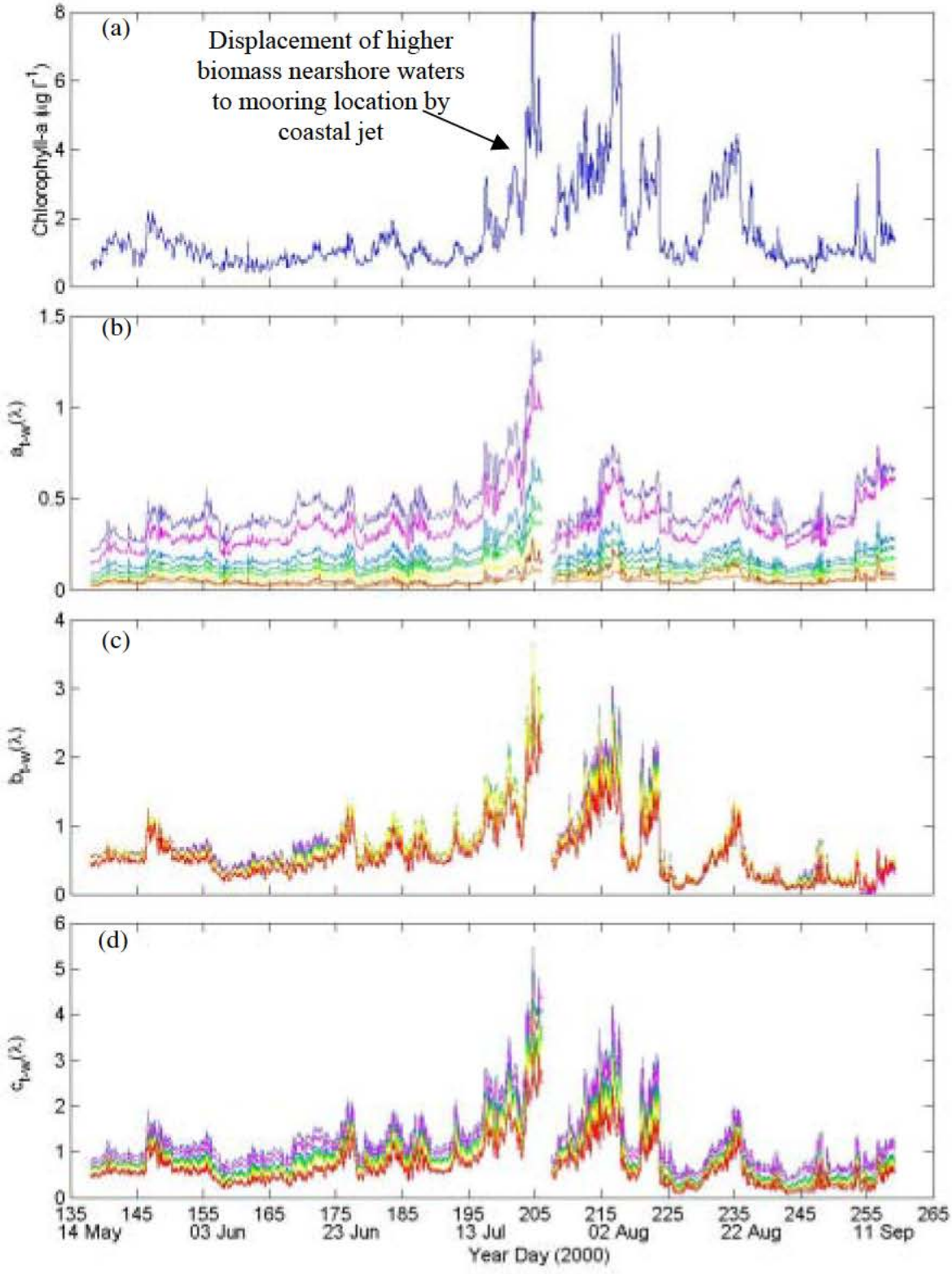

Figure 2. Time series of (a) chlorophyll-a concentration derived from the WETStar fluorometer; (b) absorption; (c) scattering; and (d) attenuation coefficients at nine wavelengths measured by the ac-9, all at 5 m water depth.

coordinated with the NRL COJET program. Hydrographic data from COJET are being used in analyses for interpretation.

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PATENTS

None